# DEVELOPMENT OF A DESIGN AND TEST PROGRAM FOR AUTOMATED COAL CAR COVERS

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# DEVELOPMENT OF A DESIGN AND TEST PROGRAM

# FOR

# AUTOMATED COAL CAR COVERS

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FOR:

Environment Canada

This manuscript has not undergone detailed technical review by the Environmental Protection Service in order to hasten the transfer of information to those people working in related studies. Mention of trade names or commercial products in this report does not constitute endorsement by Environment Canada.

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Ebco Industries

SUMMARY

The transportation of coal in British Columbia has created some environmental problems due to dusting from loaded and empty in transit coal cars. The loaded car dusting problem was somewhat resolved by profiling the surface of the loaded cars and applying a chemical binder. This methodology, however, is not foolproof and the dusting problem persists along some of the rail corridors in British Columbia. Dusting from empty unit coal trains is not affected by binder application to loaded trains and although the number of incidents is significantly fewer, dusting from these trains is also still a problem in some areas.

A secondary problem associated with the rail haul of coal along all major routes, is the potential for the build-up of ice, snow and rain in the cars.

A solution to these problems that has been considered, is the use of covers on the coal cars. It is known that this solution will not be without problems, however, recent innovations in cover design, securement systems, automatic unlatching and removal equipment, the possibility of leasing versus purchase of the covers, and fuel savings from aerodynamic drag reduction, warrants a review of the applicability of covers in the railway transportation of coal.

Studies to date have failed to resolve many of the conflicting views with respect to car covers and it is apparent that operational parameters and costs associated with automated coal car covers can only be delineated by a design and test program established to address two major areas:

(i) the technical feasibility of the covers and the handling system; and,

(ii) the economic and system feasibility of covers as part of an overall transportation system.

This report describes a methodology which could be used for developing a prototype design and test program to assess the applicability and effectiveness of an automated coal car cover system. The estimated cost of this prototype design and test program have also been included.

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## 1.0 INTRODUCTION

The transportation of coal in British Columbia has created some environmental problems due to dusting from loaded and empty in transit coal cars. The loaded car dusting problem was somewhat resolved by profiling the surface of the loaded cars and applying a chemical binder. This methodology, however, is not foolproof and the dusting problem persists along some of the rail corridors in British Columbia. Dusting from empty unit coal trains is not affected by binder application to loaded trains and although the number of incidents is significantly fewer, dusting from these trains is also still a problem in some areas.

A secondary problem associated with the rail haul of coal along all major routes, is the potential for the build-up of ice, snow and rain in the cars.

A solution to these problems that has been considered, is the use of covers on the coal cars. It is known that this solution will not be without problems, however, recent innovations in cover design, securement systems, automatic unlatching and removal equipment, the possibility of leasing versus purchase of the covers, and fuel savings from aerodynamic drag reduction, warrants a review of the applicability of covers in the railway transportation of coal.

Of particular interest are recent findings of the Association of American Railroads (AAR) Research and Test Department. Tests carried out by the AAR show that "Aerodynamic drag should be considered in designing future cars for unit train service. The potential savings in aerodynamic drag could pay for some streamlining and might justify the added cost and weight of utilizing a cover". (1)

Three major concerns have been expressed regarding the use of coal car covers and these are:

(i) the covers will be more expensive than present dust control measures;
(ii) the covers and handling systems will cause unreasonable delays to unloading and loading operations at the ports and mines; and,
(iii) the covers will fail due to repeated use and operation under harsh conditions.

Studies to date have failed to resolve many of the conflicting views with respect to car covers and it is apparent that operational parameters and costs associated with automated coal car covers can only be delineated by a design and test program established to address two major areas:

(i) the technical feasibility of the covers and the handling system; and,

(ii) the economic and system feasibility of covers as part of an overall transportation system.

This report describes a methodology which could be used, for developing a prototype design and test program to assess the applicability and effectiveness of an automated coal car cover system. The estimated cost of this prototype design and test program have also been included.

This report utilized specialists in structural design, mechanical design and railway operations to estimate the Task Lists, the manpower and the capital costs for each portion of the prototype design and test program. Additional data and input for the program was obtained from:

Strachan Henshaw;
Ecofab;
The Associaton of American Railroads, Research and Test Department
The Mechanical Engineering Department, UBC;
B.H. Levelton & Associates;
Procor Ltd
Canadian Shuttle Wagon Ltd;
Ebco Industries

## 2.0 PROJECT PLAN

### 2.1 Introduction

The general philosophy of the project plan is to technically and economically evaluate the proposed designs for covers and handling system at 4 Milestone points. At each Milestone economically unfeasible or impractical solutions will be eliminated. Subsequent Milestones will involve more detailed analysis of fewer options. The last Milestone involves refinement and limited implementation of the most promising solution.

This approach minimizes the cost of the program by ensuring that only viable options are being studied in detail and tested. In addition, if it appears that all options are uneconomic or unfeasible, the program can be terminated at the completion of any Milestone.

Reports will be prepared at the completion of each Milestone and these will be available for review and comments by interested private companies and government agencies. This will provide for input and revision of the program as it proceeds.

The Milestone titles are provided below.

I Conceptual Development

II Preliminary Design

III Detailed Design and Testing

IV Limited Implementation and Testing

Due to the complexity of the overall development program, the descriptions of the cover and the handling system programs, have been split into two sections. However, these two programs will be conducted simultaneously and will involve an integrated design team.

The following is an overview of each Milestone.

## 2.2 Project Milestones

MILESTONE I - CONCEPTUAL DEVELOPMENT

Some work has been carried out previously with the design and operation of covers and handling systems (See Reference 2 and 3). Fiberglass and steel covers are presently used on railway systems in North America, however, they are limited in use and have been designed for specific commodities and routes. The scale of applying covers to all unit train coal movements in Western Canada warrants a basic review of cover and cover handling concepts at the start of this program. This will ensure that options which might have been overlooked for other applications will be considered.

It is expected that up to 10 handling systems will be identified and just as many cover designs. These systems and designs will be compared to the design criteria and evaluated based on engineering judgement and approximate costs to yield 3 cover designs and 3 possible handling systems for preliminary design. We believe that three concepts will represent a reasonable range of options for detailed assessment in the preliminary design phase. If more concepts are required, this can be indicated in the Milestone I report and the budgets for Milestone II can be adjusted accordingly.

A report will be prepared and submitted at the end of Milestone I outlining the various options studied, the options selected, and the reasons for selection or rejection.

MILESTONE II - PRELIMINARY DESIGN

Milestone II will involve preliminary engineering, cost estimation and a transport system evaluation of the three selected concepts. No physical testing of the covers or systems will be carried out in this phase.

The preliminary engineering process will provide technical data and cost estimates which will be utilized in an overall system economic analysis. This analysis will take into account, both technical factors and transportation economic factors. Technical factors include items such as the estimated reliability of the covers and equipment while transportation factors include items such as the weight of covers and the effect of covers on reducing aerodynamic drag.

The system analysis should utilize available computer models to evaluate the impact of automated coal car covers on a given coal route such as from the South-East of British Columbia to Roberts Banks. Computer models will be used to assess the economic impact of any technical changes in the transportation system. These models are described in more detail in Section 3.2.

After completion of the system analysis, it is expected that one cover and one cover handling system will be selected for detailed design and testing.

Should more than one basic system be considered for detailed design and testing this finding should be stated in the Milestone II report and an appropriate adjustment of the budget for Milestone III will be required.

A Milestone II report will be prepared and submitted for review at the end of this stage, outlining the costs for the cover and handling system options, the results of the system analysis and the rationale for selection of a particular option. The review will involve the client and representatives from industry and other government agencies.

MILESTONE III - DETAILED DESIGN

The detailed design and testing will evaluate the technical feasibility of the proposed systems and refine the design. Testing at this stage will require involvement of shippers, railways and ports, and will involve reduced scale or full scale testing of covers and cover handling systems. For example, testing of the cover handling system could be conducted on a short, unused length of track.

The detailed design and testing program will likely result in changes to the system design or costs. The transportation economics of the system should be reviewed again utilizing the computer models developed for Milestone II. At this point the technical and economic performance of the system should be reasonably well established.

The results of the work in this phase will be presented in a Milestone III report for review by interested parties. At the conclusion of Milestone III, a decision will be made on whether it is necessary to proceed to Milestone IV.

MILESTONE IV - LIMITED IMPLEMENTATION

The next step will be to test the covers and the handling systems on a given coal movement in Canada. This would involve implementing an automated cover system on a limited trial basis on one route. Such a program would require direct involvement of the ports, mines and railways to operate and evaluate the system. The extent and cost of such an implementation program would best be estimated at the completion of Milestone III.

## 2.3 Project Activity Flow Chart

The following activity flow chart,Figure 2.1, presents an overview of the coal car cover program from Milestone I through Milestone III.

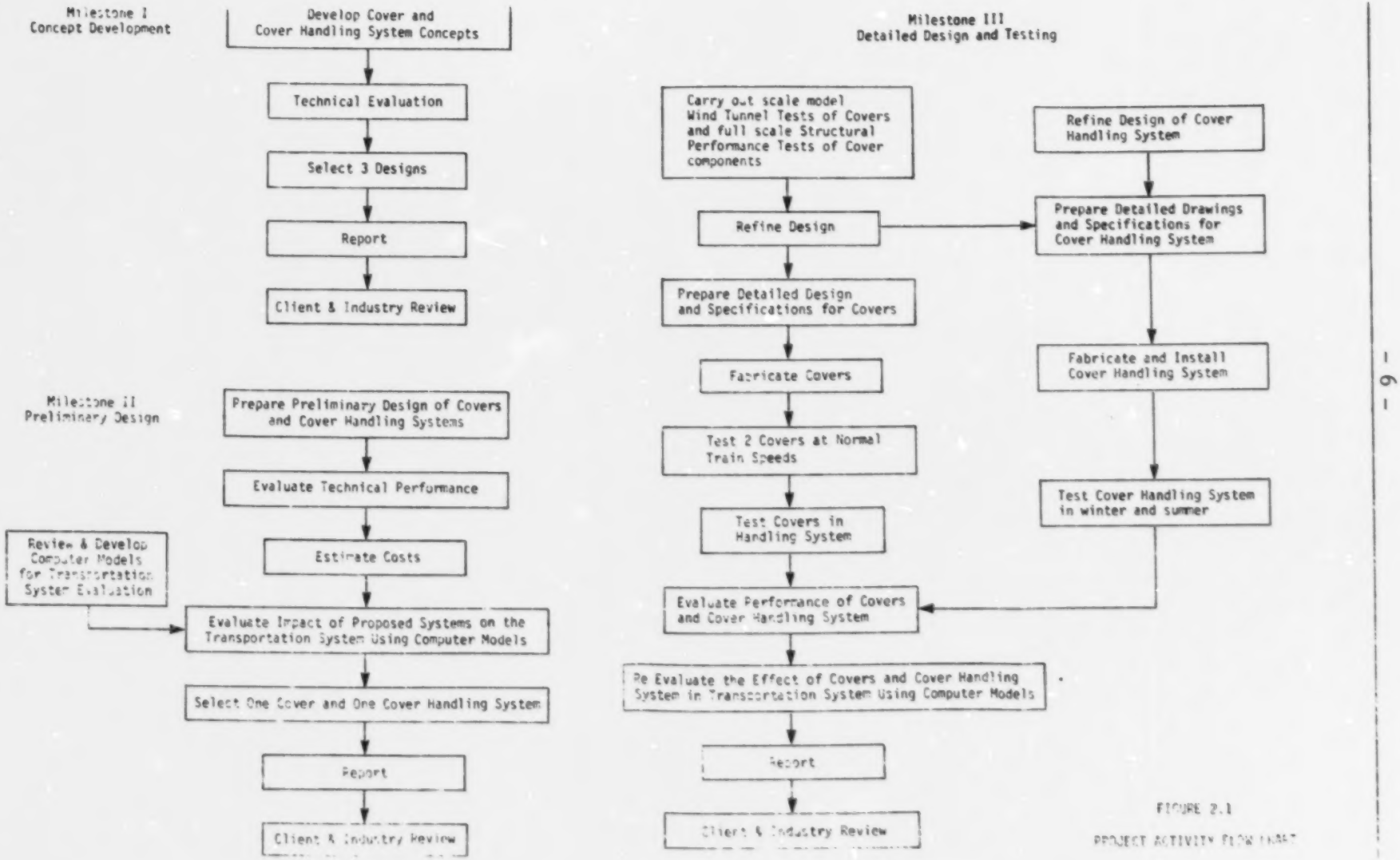



FIGURE 2.1

PROJECT ACTIVITY FLOW CHART

## 3.0 System Evaluation

### 3.1 Design Criteria

The purpose of a design and test program is to evaluate the technical and economic feasibility of automated coal car covers. A preliminary set of design criteria were defined for both the cover handling system and the covers. These criteria were used to assist in defining a program for designing and testing automated coal car covers and should be reviewed at the outset of the project. The criteria should be used throughout the project as a basis for evaluating the technical and economic performance of proposed systems.

#### Car Handling System Design Criteria

(1) Must be optimum cost.

(2) Must be compatible with various mine and port locations.

(3) Must cause only minimal delay to loading/unloading operations.

(4) Must be integrated with cover design.

(5) Must accommodate spare cover insertion and damaged cover removal.

(6) Must require minimum operator involvement.

(7) Must accommodate an automatic inspection system.

#### Cover Design Criteria

(1) Must be minimum weight.

(2) Must be optimum cost.

(3) Compatibility with handling systems.

(4) Aerodynamically designed.

(5) Cover securement system - quick release positive connection.

(6) Must prevent moisture entry and dust loss.

3.1 Cover Design Criteria (cont'd)

(7) Must be repairable and durable.

(8) Must be able to take external loads.

(9) Must permit rail cars to operate in both directions.

(10) Must result in minimum modification to the existing rail cars.

(11) Must fit all existing coal cars.

3.2 Transportation System Evaluation

In order to best evaluate the impacts of the selected cover and handling system concepts on a transport system, two types of models should be utilized:

- a Train Performance Calculator which can compute the impact of reduced drag, and changes in other technical factors on the performance of the train; and,
- an economic/financial analysis model which can accommodate discounted cash flows, financial parameters and a complete sensitivity analysis of the relevant operating, cost and financial variables

Train Performance Calculator models and economic/financial analysis models are available which satisfy both of the above modelling requirements. Some modification of these models may be required to adapt them to the study application.

Transportation factors which will be evaluated include:

- the effect of covers on retention of frozen coal in rail cars,
- the effect of cover systems in delaying mine, port and rail operations,
- the effect of the weight of the covers in reducing rail car load carrying capacity,
- the reduction in fuel consumption and consequent savings due to reduced drag,
- the elimination of the need for binder spray, and
- the elimination of product loss.

3.2 Transportation System Evaluation (cont'd)

In addition, the impact of other cost factors on overall transportation costs will be examined. These factors include capital and operating cost of the covers and handling equipment and the difference in costs between current dust control measures and automated coal car covers.

This analysis will identify either a total net benefit or a net cost and will identify those firms which benefit from covers. For example, the railways may benefit due to reduced aerodynamic drag while the shippers may benefit due to the reduction of frozen coal. In addition, the advantages and disadvantages of lease or purchase arrangements will be examined.

Additional work may be required to improve the accuracy of data such as, the impact of covers on the retention of frozen coal in rail cars and the loss of product. Little has been done to estimate the quantity of frozen coal retained in rail cars while some work has been carried out regarding coal dust losses and effectiveness of current dust control measures (See references 4-11). Estimates for improving the accuracy of data in these areas has not been included in this study. During Milestone II, research could be carried out to determine the extent and accuracy of data in these areas and recommendations made regarding the work required to improve the data.

3.3 Task List

The following is a Task List for the evaluation of cover and cover handling designs, Table 3.1. The evaluation of proposed designs in the first Milestone will largely be based on engineering judgement and as such there is no Transport System Evaluation in Milestone I. The second Milestone will involve preliminary costing and design and an assessment of the economic impact of covers and cover handling systems on the transportation system. The Third Milestone will involve a review of the economic impacts on the transportation system based on more accurate data. Detailed Task Lists outlining the work required for the handling system development and the coal car cover design can be found following the detailed descriptions of the development and design programs in Sections 4.0 and 5.0.

TABLE 3.1 TASK LIST - TRANSPORT SYSTEM EVALUATION

MILESTONE II - PRELIMINARY DESIGN EVALUATION

(i) Review existing train performance/economics models. Select one for modification for testing rail car cover transportation cost impacts.

(ii) Modify the model to suit the evaluation requirements of the test program.

(iii) Set up the model to evaluate coar car covers on a given route.

(iv) Review data developed by test program engineers and obtain data from other sources, such as quantity of frozen coal retained in cars and loss of product through blow off.

(v) Identify the range of variation in input variables and carry out sensitivity analysis.

(vi) Based on computer model analysis describe the economic and technical impact of coal car covers on the transportation of coal by rail in Canada.

(vii) Make recommendations as to the relative benefit or costs of coal car covers.

(viii) Make recommendations as to the need for further work in Milestone III to improve accuracy of data.

MILESTONE III - DETAILED DESIGN AND TESTING EVALUATION

(i) Review data developed by the test program and other studies.

(ii) Re-run model to determine the impact of coal car covers on the transportation system based on more accurate data.

(iii) Carry out a financial analysis and examine the options of lease versus purchase of covers and handling systems.

(iv) Comment on the relative benefits of costs of coal car covers and make recommendations on the need for further work.

## 4.0 HANDLING SYSTEM, DESIGN AND TESTING

### 4.1 Milestone I - Conceptual Development

The development of concepts for the handling of rail car covers must take into account the nature of existing coal transportation operations.

Most western coal is loaded by a flood loading method with the train in continuous motion at a speed of approximately 0.8 km/h (0.5 mph).

Train unloading is by rotary dump systems with mechanical indexing without uncoupling the rail cars. Cycle times per car for this operation may vary from 120 sec for older single indexers (during this period the rail cars may be stationary for approximately 45 sec), to approximately 96 sec with modern tandem dumper and twin indexer installations. With these newer installations, the train can be considered to be practically in continuous motion at a speed of approximately .66 m/sec (2 feet per sec).

Cover handling equipment must be capable of operating within these cycle times and be capable of handling two cars simultaneously when used with tandem car dumper installations.

It may be possible to design and test a cover handling system which could function at both the ports and mines. However the train is in continuous motion at the mine while loading and unloads in a stop-go mode at the port. This may necessitate the testing of 2 types of handling systems.

Three major factors are to be considered in establishing the type of cover handling system to be designed and tested:

(1) As the equipment is to be used on existing installations the design of the cover handling equipment should be such that it can be added with minimum modification to the existing plant.

(2) If practical, the basic system should be compatible with both loading and unloading installations.

(3) Any system chosen should perform its function with minimum interruption to the existing operations.

Previous reports suggest that the system which would incur minimum modifications to existing installations would be one in which the covers are completely removed from the car and carried to the side and around loading/unloading installations for replacement after loading/unloading. Other systems including an up and over operation in order to avoid possible existing structures adjacent to the unloading stations should also be investigated.

In addition to the above, a review should be carried out to identify other possible concepts. This concept development for cover handling systems will take into account ideas for cover design and the various materials for the fabrication of covers. It is expected that up to 10 concepts will be identified and because of the relatively high costs for studying this number of concepts in greater detail, approximately 3 will be selected for further development.

A handling system report will be prepared following the selection of the 3 concepts. This report would be incorporated with the report covering the conceptual development of the covers, to form a complete Milestone I report. The report should describe each of the studied concepts, provide graphics as available, and should detail reasons for acceptance or rejection of each concept. The report will be distributed to interested parties as directed by the Canadian Government.

An allowance of 8 weeks should be provided following the completion of the report, to allow for review, comments, or revision of the report.

4.2 Milestone II - Preliminary Design and Costing

After the review and acceptance of the Milestone I report, and the decision to proceed has been given, preliminary design and cost estimates of the concepts will be prepared. This would involve the preparation of preliminary drawings of the system, with sufficient details to allow budget price estimates to be obtained for suppliers. The work at this stage of the program would involve discussions with terminal operators and mining companies to obtain their input. All estimates and other input will be correlated and a systems assessment of the covers and the handling systems will be carried out to determine the best concept to be selected for detailed design.

Based on a systems assessment, one of the preliminary designs will be selected for further development, and a Milestone II report will be prepared. As with the previous Milestone report, the Milestone II report would incorporate the findings and recommendations of the cover assessment into a single report.

The report should present the details of the work completed including designs and costs for all concepts, the concerns and comments from the terminal operators, and the results and recommendations from the system assessment.

An allowance of 8 weeks should be provided following the completion of the report to allow for review and comments, by private industry and government agencies.

4.3 Milestone III - Detailed Design and Testing

When the review, acceptance and the decision to proceed with the next phase has been received, detailed design of the selected handling system will be prepared including the preparation of drawings and specifications. Tenders will be called for the fabrication, installation, operation and monitoring of the prototype equipment at the selected location(s).

4.3.1 Performance Testing

The testing of cover handling equipment should be carried out on any suitable length of test track. It is assumed that trackage for this test would be made available at no cost from one of the railway companies. If it is not possible to obtain trackage, it will be necessary to construct or lease trackage at a suitable location.

It is recommended that the test program be carried out over a 6 month period during which time the practicality of the system would be evaluated and an indication of the wear and tear on the covers and rail cars could be obtained. Three months of the test program should be carried out during winter and three months during summer.

The approach will be to set up the handling system on a track and lease or obtain 20 rail cars similar to those in use on Canadian unit coal trains. It is most likely that the cars would have to be leased through an arrangement with a rail car supplier. At present there is no surplus of coal cars in Canada. The cars would be assembled in a string, fitted with the prototype covers and pulled back and forth through the handling system on a continuous basis. It would be necessary to lease a car mover to provide the motive power to move the cars at the test track.

The major objective of this test exercise will be to evaluate the performance of the handling equipment, however, the performance of the cover securement system and the durability of the cover will also be of interest. Major changes to the type or shape of the cover are not expected. However, should they occur, additional review of the handling system and some design changes may be required.

It is expected that 30 covers will be required for this test phase: 20 for continuous operation and 10 to account for damage and to provide a reserve. The handling system may be designed to hold a surplus of covers so that damaged covers can be automatically removed and new or repaired covers inserted.

The evaluation would include monitoring for reliability of the equipment and system performance. Factors of interest will be the impact of the equipment on overall loading and unloading rates, damage to covers, performance of securement systems and operation of the equipment under harsh conditions such as high winds, cold temperatures, etc. During this time refinements may be made to the final design based on the results of the test program. Depending on the number and severity of the refinements extensions to the schedule may have to be made.

## 4.4 Task List

The following Task List describes the work required to complete each milestone in the handling system development including an estimate of the time required, Table 4.1.

TABLE 4.1 - TASK LIST - HANDLING SYSTEM DESIGN

| MILESTONE | | | Estimated* Duration (Weeks) |
|---|---|---|---|
| I | | CONCEPTUAL DEVELOPMENT | |
| | (i) | Review work carried out by others, including visits to locations in North America where existing systems are in operation. | 4 |
| | (ii) | Develop new concepts in close co-operation with cover designers, terminal and mine operators and the railways. | 4 |
| | (iii) | Perform preliminary evaluation of potential concepts, highlighting system trade-offs, advantages and disadvantages and select suitable concepts for further study. | 2 |
| | (iv) | Prepare Milestone report and circulate for review and comments by interested parties. | 2 |
| II | | PRELIMINARY DESIGN AND COSTING | |
| | (i) | Prepare preliminary designs and drawings of concepts in sufficient detail. | 6 |
| | (ii) | Liaise with mine and terminal operators to obtain their input. | 2 |
| | (iii) | Prepare capital and operating costs using the data prepared in (i) and (ii) above. | 3 |
| | (iv) | Utilize existing computer models and evaluate system handling options based on model outputs. | 4 |
| | (v) | Select one design for further detailed design and refinement. | 3 |
| | (vi) | Prepare Milestone report and circulate for review and comments | 3 |

TABLE 4.1 - TASK LIST - HANDLING SYSTEM DESIGN

| | | Estimated* Duration (weeks) |
|---|---|---|
| III | DETAILED DESIGN AND TESTING | |
| (i) | Refine selected prototype design based on computer model output. | 3 |
| (ii) | Liaise with terminal and mining operators to obtain their detailed output. | 2 |
| (iii) | Prepare detailed drawings, specificatins and tender documents. | 6 |
| (iv) | Issue and close tenders, make evaluations and recommendations. | 8 |
| (v) | Award contract and supervise construction and start-up (allow for construction problems and delays). Design monitoring and data evaluation system. | 40 |
| (vi) | Operate the system over the test period. (3 months in winter and 3 months in summer). | 40 |
| (vii) | Re-run computer models using operational data from the test period, and evaluate the data. | 6 |
| (viii) | Based on field modifications and the computer analysis refine final design. | 4 |
| (ix) | Estimate cost of final design. | 2 |
| (x) | Prepare Milestone report and circulate for review and comments. | 2 |

*NOTE: Some of these steps are concurrent - refer to CPM Network Diagram, Figure 6.2.

## 5.0 COVER DESIGN AND TESTING

### 5.1 Milestone I - Conceptual Development

The initial phase of the cover development provides for the review and conceptual development of cover designs. These concepts will likely include flexible and rigid covers utilizing various types of materials, such as steel, aluminum and fiberglass.

The conceptual development of the covers will provide a number of designs, but because of the prohibitive costs of further design and development, the review process should yield 3 of the most promising concepts for further development.

A Milestone I report will be prepared outlining the concepts studied, and the covers recommended for further study.

### 5.2 Milestone II - Preliminary Design

The selected cover concepts will be developed further so that an estimate of their potential performance and costs can be made. This will involve the preparation of drawings and specifications and design refinements using structural finite element models.

Finite element models are specialized structural computer models utilized to assist in designing structures subjected to unusual load patterns or unusual shaped structures. This will require a significant amount of co-ordination with the cover handling design team. It is also anticipated that significant design attention will be focused on the securement system. One of the three designs will be selected based on the anticipated costs and performance.

The results, recommendations and selection will be summarized in the Milestone II report, and subject to the review of the report, the detailed design and prototype construction of the selected design will commence.

### 5.3 Milestone III - Detailed Design and Testing

Detailed design of the selected cover will include wind tunnel and structural performance testing of a prototype cover. These tests will allow for further design refinements of the cover before production and limited implementation.

5.3.1 Wind Tunnel Testing

Current testing by the Association of American Railroads(AAR), Research and Test Department have been general in nature, and designed to determine whether covers reduce aerodynamic drag.

Telephone conversations with Mr. Cataldi of the AAR Research Test Department reveal that the AAR intends to carry out testing of full scale covers to further refine the results of the scale model testing program.

We have recommended that a wind tunnel test program be carried out to assist in refining the shape of the cover for two purposes: to reduce the probability of cover blow off and to reduce drag.

The appropriate size of the scale model to be used for the tests would be determined during the design phase and would take into account the testing procedures, costs, etc.

5.3.2 Structural Performance Testing

Once the wind tunnel testing program is complete, a full scale testing of critical components such as securement systems, main structual members will be carried out. Destructive and non-destructive tests will be carried out to assess the performance of these components. The results of these tests will be compared with the results of the Finite Element analysis to establish a correlation.

5.3.3 Design Refinement and Testing

Design refinements of the covers will be carried out using data from the wind tunnel analysis, the structural performance tests, and the finite element analysis. Testing of the covers in operation will then be carried out. The purpose of this testing will be to determine the performance of the covers in continuous operation at normal train speeds of 50 to 80 km per hour. Two covers will be fitted with monitoring equipment such as strain gauges and extensiometers. This evaluation will be carried out for a period of 3 months. The data from the instrumentation system will be used to formulate further design refinements and modification for production models.

5.3.3 Design Refinement and Testing (cont'd)

A possible test location is the Association of American Railroads (AAR) Test Track Center in Peublo, Colorado. Discussion with personnel at the Test Track Center reveal that the Facility for Accelerated Service Testing (FAST) would be most appropriate for testing the covers. The following is a description of FAST provided by the Transportation Test Center (TTC):

> "A major continuing test series at TTC since 1976 has been conducted on the Facility for Accelerated Service Testing - FAST. Essentially a high-utilization railroad, FAST was designed to compress time and to determine as quickly as is feasible the effects of extended service on track and equipment components. The equipment and facilities provide TTC with unique, controlled-condition, high-utilization capabilities that are entirely isolated from the problems inherent in superimpsoing tests on everyday operations.
>
> The train is composed of locomotives and cars that are on loan from AAR member railroads. The operations are supported by, essentially, a "one-stop" car repair shop designed to perform all necessary measurements on equipment components. The result is a unique, controlled-condition railroad proving ground.
>
> The facility is open to commercial testing. The 4.8-mile loop is divided into 22 test sections, into which may be inserted any track component - rail, fastenings, cross-ties, ballast - that requires evaluation. There is room in the train for cars under commercial development".

The major Canadian railways are members of the AAR, and as such, provide rail cars to this facility. Arrangements would have to be made with the Canadian railway companies to utilize Canadian coal cars for testing the covers at FAST.

5.4 Task List

The following Task List, Table 5.1, describes the work required to complete each milestone in the rail car cover design including an estimate of the time required.

TABLE 5.1 TASK LIST - COVER DESIGN AND TESTING

| | | Estimated* Duration (weeks) |
|---|---|---|
| I | CONCEPTUAL DEVELOPMENT | |
| | (i) Review previous work done (by others) on railcar covers including visits to locations in North America where existing systems are in operation. | 4 |
| | (ii) Develop new concepts in close co-operation with cover handling system designers, the railways and the mine and terminal operators. | 4 |
| | (iii) Perform preliminary evaluation of potential concepts, highlighting system trade-offs, advantages and disadvantages and select suitable concepts for further study. | 2 |
| | (iv) Prepare Milestone report and circulate for review and comments. | 2 |
| II | PRELIMINARY DESIGN | |
| | (i) Perform preliminary design to determine geometry, load transfer patterns and section properties.<br><br>Develop finite element models for static and dynamic analysis of selected designs. Identify potential static and dynamic loading scenarios.<br><br>Analyze selected concepts for the range of loading scenarios, evaluate results and highlight potential stress concentrations.<br><br>Research potential securement systems. | 6 |
| | (ii) Select appropriate material (steel, aluminum fiberglass, etc).<br><br>Estimate costs and performance of selected covers. | 3 |

PRELIMINARY DESIGN (cont'd)

| | | |
|---|---|---|
| (iii) | Utilize existing computer models and evaluate cover designs based on model outputs. | 4 |
| (iv) | Select one design for further detailed design and refinement. | 3 |
| (v) | Prepare Milestone report and circulate for review and comments. | 3 |

| | | Estimated* Duration (weeks) |
|---|---|---|
| III | DETAILED DESIGN AND TESTING | |
| (i) | Refine structural designs on the basis of computer model analysis, and finite element models.<br><br>Selection and detailed design of a securement system. | 2 |
| (ii) | Determine appropriate scale model for wind tunnel testing of covers and construct models. | 4 |
| (iii) | Perform wind tunnel tests to assist in designing the shape of the covers and to confirm and quantify the beneficial effects of covers.<br><br>Wind tunnel tests will be carried out in two phases. The first phase will consist of the following:<br><br>. empty, without covers<br>. full, with covers, and<br>. with flexible and/or rigid covers.<br><br>The second phase will consist of evaluation of cover geometries to determine the most effective geometry within the confines of structural and handling system requirements. | 3 |
| (iv) | Design and construct full-scale model of the critical components of the selected concepts for performance evaluation under static and cyclic loading. | 4 |

DETAILED DESIGN AND TESTING (cont'd)

| | | |
|---|---|---|
| (v) | Perform non-destructive and destructive testing of critical components and monitor structural integrity and performance.<br><br>Compare test results with Finite Element analysis results to establish correlation. | 3 |
| (vi) | Modify and refine cover designs on the basis of the results obtained from wind tunnel and structural performance testing. | 4 |
| (vii) | Prepare drawing, specifications and estimate material quantities and fabrication costs. | 6 |
| (viii) | Design instrumentation package (strain gauges, extensiometers, etc) and data acquisition system for evaluation and monitoring of 2 prototype covers under actual operating conditions. Construct prototype covers including handling system requirements. | 20 |
| (ix) | Test prototype covers | 40 |
| (x) | Re-run computer models using operational and performance data from test period. | 2 |
| (xi) | Evaluate data obtained from computer model output and instrumentation system and formulate further design refinements and modifications for production models. | 8 |
| (xii) | Prepare final cost estimates for production models. | 2 |
| (xiii) | Prepare Milestone report and circulate for review and comments. | 2 |

* NOTE: Some of these steps are concurrent - refer to CPM Network Diagram, Figure 6.2.

## 6.0 PROGRAM COSTS AND CONCLUSIONS

The design team composition, design costs and prototype testing costs are described in this section.

### 6.1 Project Team Composition

The project team will consist of mechanical engineers, structural engineers, computer specialists, materials and instrumentation engineers, railway transportation engineers and, economists. This team should be managed by an individual with skills in managing a multi-disciplined team.

The team will be organized into groups with the following responsibilities:

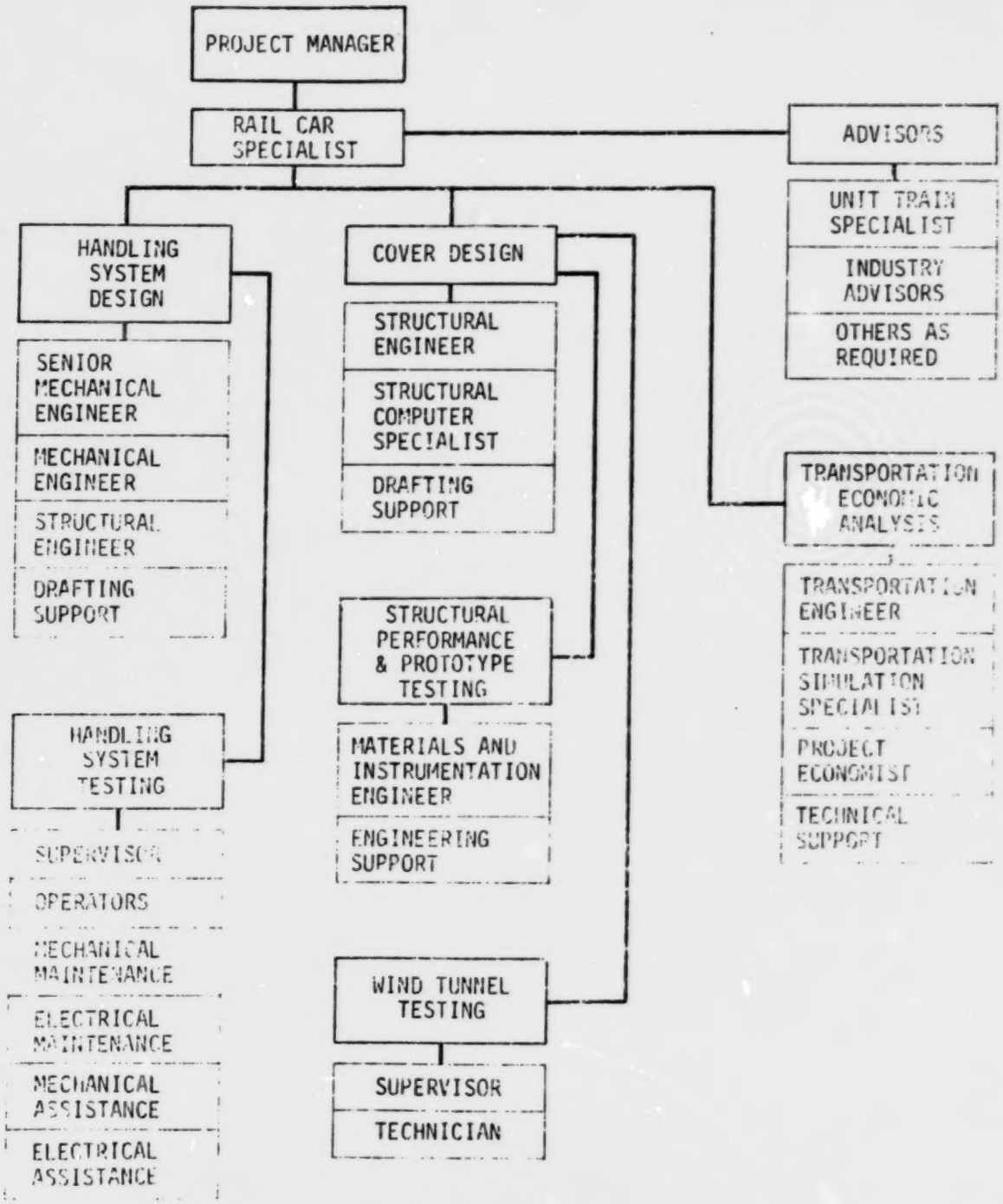
Cover Handling System Design
Cover Design
Transportation Systems and Economics Analysis
Cover Handling System Testing
Structural Performance Testing (Cover)
Wind Tunnel Testing (Cover)

The cover design and cover handling system design teams will work closely together. Integration of all aspects of the design and development of the cover and cover handling system are required for this project to be successful.

Specialist advisors will be employed to provide input into the various phases of the design process. It is anticipated that these will include rail car design and maintenance specialists, and unit train operations specialists.

Figure 6.1, following shows a Project Team Organization Chart.

FIGURE 6.1 PROJECT TEAM ORGANIZATION



## 6.2 Project Design Costs

Based on the task lists and project team previously outlined, the cost of designing, preparing drawings and procuring covers, cover handling systems and tests are outlined in Table 6.1. The costs are broken down by Milestone.

Design costs included fees for management, engineering and preparation of drawings, specifications and tender documents, review and selection of bidders and supervision of fabrication of covers and cover handling systems. Expenses such as travel, computer analysis, communications, reproduction and miscellaneous items are also included in the design costs. A 20% contingency was added to the basic design cost estimate as this is a research oriented project which may involve changes from the anticipated work plan.

The Milestone reports will indicate the findings of the study and outline detailed terms of reference and budget estimates for the subsequent stage of work. The project can be terminated at the completion of Milestone II or Milestone III if the transportation system and economic analysis shows that covers are not a viable proposition. The total design costs for this program would be approximately $779,000.

TABLE 6.1

ESTIMATED PROJECT DESIGN COSTS

| Milestone | I | II | III | Total |
|---|---|---|---|---|
| Cover and Handling System Design | $35,000 | $195,000 | $330,000 | $560,000 |
| Transportation and System Economic Analysis | --- | $60,000 | $35,000 | $95,000 |
| Sub-total | $35,000 | $255,000 | $365,000 | $655,000 |
| Add 20% contingency to Milestones II & III | -- | $51,000 | $73,000 | $124,000 |
| Total Costs including Contingency | $35,000 | $306,000 | $438,000 | $779,000 |
| Cumulative total costs | $35,000 | $341,000 | $779,000 | |
| Total Man Months | 4 | 20 | 36 | 60 |
| Cumulative total months | 4 | 24 | 60 | |

NOTES: Design costs include expenses such as computer costs, travel communications, reproduction, etc.

All costs are budget estimates and will vary depending on the actual design and test program selected.

All costs 1985 Canadian dollars.

For total cost summary see Table 6.3.

## 6.3 CPM Network Diagram

A CPM Network has been developed for the design and test program and is shown in Figure 6.2. All times are in weeks and the Project Milestones have been highlighted.

Milestone I will take 9 weeks to complete and Milestone II 21 weeks. Review of the Milestone reports at the completion of these Milestones has been estimated at 8 weeks.

The Milestone Reviews, are on the critical path, therefore, any change in the 8 week review time will directly effect the overall schedule of the project.

From the end of the Milestone II report review, to the completion of Milestone III, the Critical Path, (shown * on the diagram), follows the handling system design and construction, through to the preparation of the Milestone III report. It is estimated that Milestone III will take 113 weeks to complete.

One activity within this Milestone which could present possible problems with the schedule is activity SC01 - Construct Handling Facility. An estimated 40 weeks duration has been allowed, however, if construction or startup problems arise this estimate may have to be increased, thereby affecting the overall completion schedule.

Within the Milestone III schedule, there is 20 weeks of float time for the cover design/testing and the prototype construction, which allows flexibility in this area.

An estimated 159 weeks will be required for the overall project, from start to completion of the Milestone III Report.

## 6.4 Test Costs

Test costs have been estimated based on the design program requirements and data provided from the various sources, including Strachan Henshaw, Ecofab, AAR, B.H. Levelton & Associates, Procor Ltd, Canadian Shuttle Wagon and the Mechanical Department, UBC. The testing program comprises a number of components which are detailed earlier in this document and are summarized here for convenience.

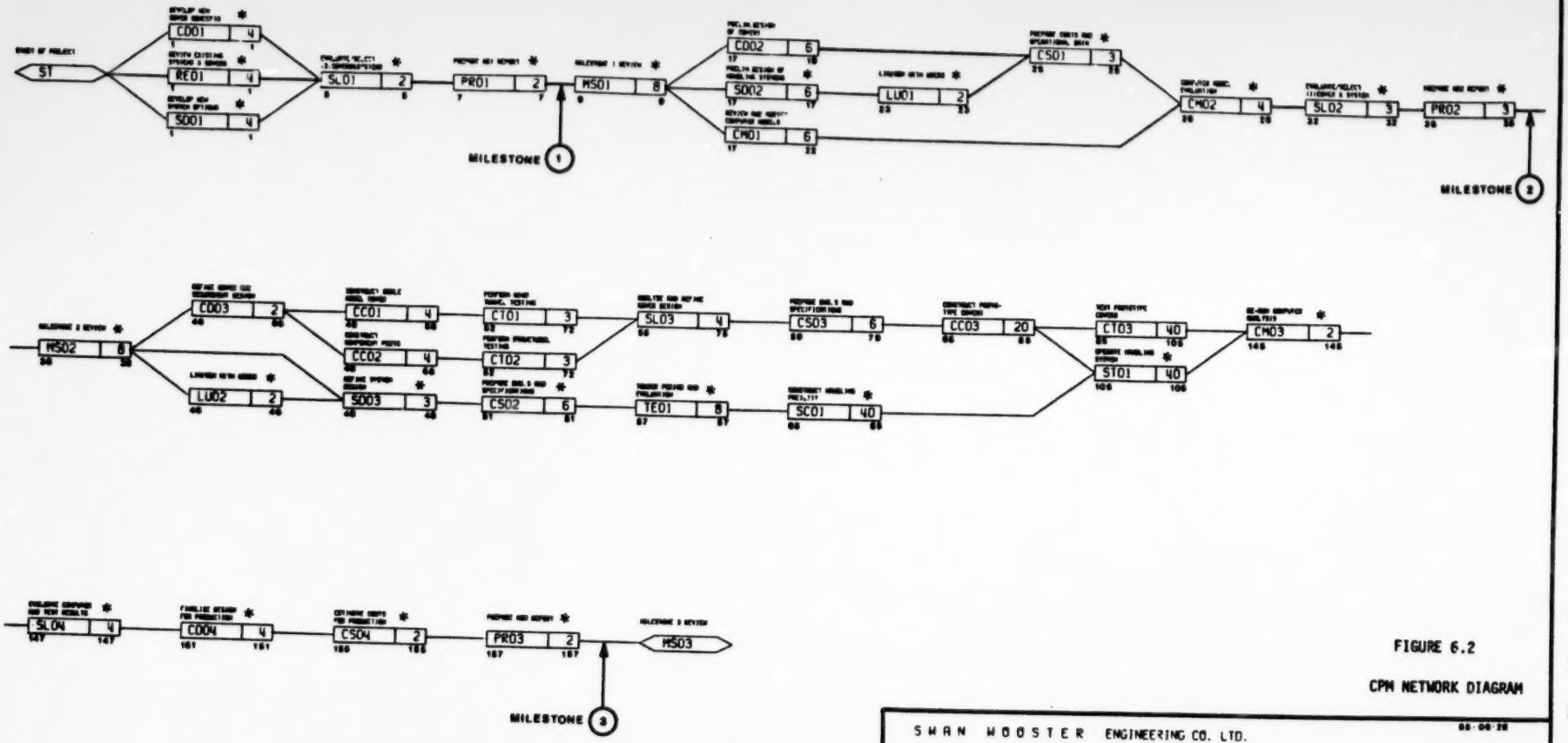



FIGURE 6.2

CPM NETWORK DIAGRAM

SWAN WOOSTER ENGINEERING CO. LTD.

AUTOMATED COAL CAR COVER-DESIGN AND TEST PROGRAM

CPM NETWORK LEGEND

ACTIVITY — DESCRIPTION | LABEL | DUR. | Early Start | Late Start

EVENT — DESCRIPTION / LABEL

* -INDICATES CRITICAL ACTIVITY

Duration and Early/Late Start Times Are In Weeks

6.4 Test Costs (cont'd)

The cover testing program consists of three components all carried out in Milestone III:

- wind tunnel testing of scale models;
- non-destructive and destructive testing of major components of the cover;
- full scale testing of covers in operation on railcars.

The cover handling program testing consists of fabricating a full scale cover handling facility and operating it for a period of 3 months in the winter and 3 months in the summer.

The costs shown here assume that one handling facility will be required, however operational differences at the mine and port may dictate the two systems be designed and tested.

A cost of $1.17 million was estimated for a cover handling system in a 1982 study (2). At an average rate of inflation of 5% this would amount to $1.35 million in 1985. We have estimated a cost of 2.0 to 2.5 million for a prototype test. This higher estimate is based on our past experience and judgement that a prototype system will be more costly. To obtain a more accurate estimate, preliminary design of the system would have to be prepared.

Approximately 1000 meters of track will be required to carry out the testing and it was assumed that unused trackage could be made available at no cost by one of the railway companies. Rail cars would have to be leased at approximately $750 per month for several months. An additional $5000 was allowed for delivery costs, and other unforeseen costs associated with leasing the cars.

The number of covers required for testing purposes has been estimated to be 32; 30 for testing the performance of the cover handling equipment and 2 for testing the performance of covers while on a train.

Cost estimates for rail car covers fabricated in steel, aluminum and fiberglass were based on concepts developed in the 1982 study (2), in-house data and information provided by suppliers (noted in Section 1.0). The unit costs for covers are as follows:

. Steel$ 8000 . Aluminum $12,000 . Fiberglass $ 5000

The fiberglass covers would require a mould costing $25,000.

The previous study recommended the use of fiberglass covers as they best satisfied the design criteria and therefore, our costs for covers based on testing fiberglass covers. Should the study team decide to utilize aluminum covers, for example, rather than fiberglass, the cost of the test program will be substantially higher. Table 6.2 outlines the cost components of the test program and the total costs. The total test costs including a 20% contingency amount to approximately $3.85 million.

## TABLE 6.2

## FABRICATION AND TESTING COSTS

| | | Milestone III |
|---|---|---|
| **Covers** | | |
| 1. | Wind Tunnel Testing | $ 20,000 |
| 2. | Construct Model(s) | 2,000 |
| 3. | Non-destructive and destructive testing of major components | 30,000 |
| 4. | AAR Test Facility Charge | 20,000 |
| 5. | Instrumentation & Data | 70,000 |
| | Sub-Total | $142,000 |
| **Handling System** | | |
| 1. | Capital Cost of supply and installation | 2,500,000 |
| 2. | Operating - personnel (6 months) | 130,000 |
| 3. | Maintenance and Energy (based on 2% of Capital Cost) | 50,000 |
| 4. | Covers | |
| | . fiberglass, mould | 25,000 |
| | . 32 covers ($5000 each) | 160,000 |
| 5. | Rail Car Leasing (20 cars-9 months) | 150,000 |
| 6. | Motive Power Leasing (9 months) | 50,000 |
| | Sub-Total | 3,065,000 |
| | TOTAL | 3,207,000 |
| | Contingency 20% | 640,000 |
| | TOTAL COST | $3,847,000 |

NOTES: All costs are budget estimates and will vary depending on the actual design and test programs of the cover and cover handling system.

All costs in 1985 Canadian dollars.

For total cost summary see Table 6.3.

## 6.5 Conclusions

The total cost to carry out a design and test program to completion of Milestone III will be approximately $4.6 million. At the completion of Milestone II the costs and schedule for Milestone III will be better defined. For example, the type of cover will be known and the type and number of cover handling systems will be known. A period of 9 to 10 months and a total of $341,000 is required to complete Milestones I and II at which point a decision can be made whether to proceed with further design, construction and testing. Table 6.3 is a summary of design, fabrication and testing costs by Milestone.

TABLE 6.3

SUMMARY OF SCHEDULE, DESIGN & TEST COSTS

| Milestone | I | II | III | Total |
|---|---|---|---|---|
| Design* | $ 35,000 | $306,000 | $ 438,000 | $779,000 |
| Construction** and Testing | -- | -- | 3,847,000 | 3,847,000 |
| Total | $ 35,000 | $306,000 | $4,285,000 | $4,626,000 |
| Cumulative total | $35,000 | $341,000 | $4,626,000 | |
| Weeks to complete | 9 | 29*** | 121**** | |
| Cumulative weeks | 9 | 38 | 159 | |

*Taken from Table 6.1

**Taken from Table 6.2

***Including MSI Review and longest path length

****Including MS II Review and longest path length

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Swan Wooster Engineering Co Ltd, Beak Consultants Ltd, Barron and Associates and Thomas Associates.